

tential temperature. The release of the heat of vaporization from the water vapor upon condensation at any point causes an increase of potential temperature at that point. Thus a lowering of the potential temperature surfaces in the saturated layers occurs.

The transformation from unsaturated to saturated conditions in a region on the isentropic chart is marked by a decrease in the slope of the potential-temperature surfaces. The moist tongues usually flow up a "valley" of the isentropic surface and the effect of saturation in such a "valley" is to change its shape by this decrease in slope.

With a dense network of upper-air soundings in the moist region one would expect to be able to trace the flow in the saturated layers of ascending air by means of the surfaces of equivalent-potential temperature. These would always have a greater slope than the potential-temperature surfaces in the region of saturation. After some experience in constructing isentropic charts where saturation was indicated, it was realized that the lapse rate in the air in the region of saturation should be almost exactly the pseudoadiabatic as a result of stirring within the air layers in question, producing constant equivalent-potential temperature in the vertical. Therefore identification of the surface of constant equivalent-potential temperature is not possible because it is not a surface, but a layer of finite thickness.

The analysis of the two isentropic charts for February 3, 1938 is shown in figures 2 and 3, and the pressure differences between the 295 and 299 surfaces are plotted in figure 4. It will be noted that in the region of saturation the pressure difference is about 100 mb. This is exactly the difference corresponding to a constant equivalent-potential temperature vertically in the layer.

It is possible to carry these ideas farther and state that if the pressure difference between the two surfaces is less than that indicated for constant equivalent-potential temperature (lapse rate less than pseudoadiabatic) it is possible to trace the constant equivalent-potential temperature surface along which the air would move after saturation. However, it is probable that in cases of prolonged cloudiness and precipitation the lapse rate is close to the pseudoadiabatic, a fact which seems to be borne out by observation. Accordingly, no matter what the value of the pressure difference between isentropic surfaces may be in a given region before saturation, after saturation it will soon become equal to that corresponding to a constant equivalent-potential temperature. Further investigations into these various possibilities are contemplated.

*Conclusion.*—The thermodynamic isentropic chart has the following advantages over the chart based on elevations and specific humidities:

1. Better representation of significant moisture differences at low values. Moist tongues at low temperatures show up as well as those at high temperatures; not so on the other type of chart where with winter temperatures over the continent they may not even appear at all.
  2. Nearness to condensation can be determined by the "condensation ratio"  $p_0/p$  directly from the chart and especially by noting on the chart the distance separating a  $p_0$ -isobar and a  $p$ -isobar of equal value. This cannot be shown directly with  $q$ -isograms. The ratio  $p_0/p$  is the only expression of the nearness to saturation that is of direct thermodynamic significance in an isentropic process.
  3. Areas of saturation are indicated directly.
  4. A method of indicating the flow under saturation-adiabatic conditions is provided.
  5. Isotherms can be indicated easily, a given temperature being everywhere at the same pressure. This is useful for aeronautical purposes in indicating the location of the freezing isotherm.
  6. The weight of air in the layers between isentropic surfaces can be read off immediately.
  7. Cold lows appear as regions of greater activity and warm highs as less active than on the other type of chart.
  8. The greater ease of preparation is a distinct advantage. Pressures can be read off directly from the adiabatic chart without the labor of constructing an altitude curve.
- While the thermodynamic uses of the chart have been indicated principally in this paper, it should be noted that advantages listed under 1, 4, 6, and 7 above also accrue in the use of the chart for strictly hydrodynamical purposes. There appears to be no reason why the type of chart advocated here is not preferable for practically all uses, and if only one chart is drawn in daily synoptic practice the one recommended here is distinctly preferable.
- It might be argued that the use of  $p_0$ -isobars does not permit a good measure of the transport by horizontal turbulence, which is proportional to the gradient of specific humidity,  $-\nabla q$ . At saturation this latter relationship will not hold because there can be no net transport horizontally in this stage; yet  $-\nabla q$  will not be zero except along an isobaric surface. In daily synoptic practice an exact computation of the horizontal transport usually is not attempted, although there is no reason why it should not be possible to compute it with a fair degree of reliability. Unless it can be shown that the horizontal transport can be expressed in terms of  $p_0$  in place of  $q$ , the method advocated here will have therefore a disadvantage in this one respect.

## RELATION OF PRESSURE TENDENCIES TO CYCLONES AND FRONTS

By W. R. STEVENS

[Weather Bureau, New Orleans, La., February 1938]

One of the most important elements for forecasting purposes contained in weather reports is the 3-hour pressure tendency. The method developed by Petterssen<sup>1</sup> for determining displacements of pressure centers, wedges, troughs, and fronts, is one of the most valuable tools at the disposal of the forecaster and is based largely on 3-hour pressure tendencies.

It is generally recognized that tendencies are valuable in analysis as well as in prognosis. To illustrate their value, the writer has prepared a set of model moving cyclones, with and without frontal structures. Attention

is invited to a study in which Bowie<sup>2</sup> used the same general method in connection with 12-hour pressure changes.

It is emphasized that the 3-hour pressure tendency is only one of many criteria for recognition of a front, and that other data must be given proper consideration.

Each diagram indicates the position of a cyclonic pressure system at the time of observation, as well as 3 hours previously, with attendant pressure changes and characteristics. The changes are larger than ordinarily observed in a 3-hour period, but this is unimportant since they may be divided by any number without affecting the characteristic, which is really the most important factor in analysis.

<sup>1</sup> Petterssen, S.: Kinematical and Dynamical Properties of the Field of Pressure with Application to Weather Forecasting. Geofysiske Publikasjoner vol. X, No. 2.

<sup>2</sup> Bowie, E. H.: On Pressure-Change Charts, Mo. Wea. Rev., 44: 132-133.

The low-pressure charts of the models are all assumed to be moving without acceleration in a straight line. A radical change in direction of movement of a warm-sector

warm front are steadily falling and are leveling off in the warm sector with a rather large area where the pressure has been steady. The cold front naturally is marked by

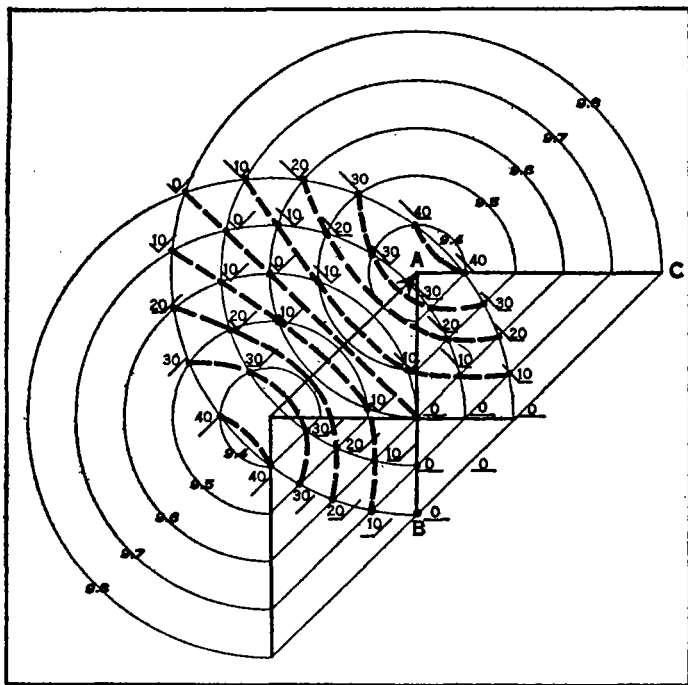


FIGURE 1.

cyclone does not occur within a 3-hour period. Acceleration in a straight line within the same period, while more likely to occur, will have no effect on the net change although the characteristic will be slightly modified.

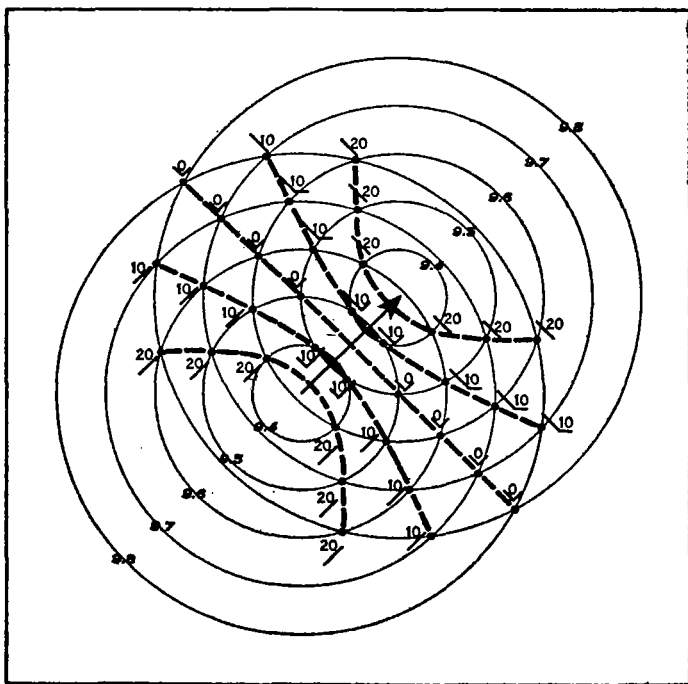


FIGURE 2.

Figure 1 represents a warm-sector cyclone without change in intensity with the cold front AB and the warm front AC retaining the same positions relative to the moving system. It is noted that the tendencies at the

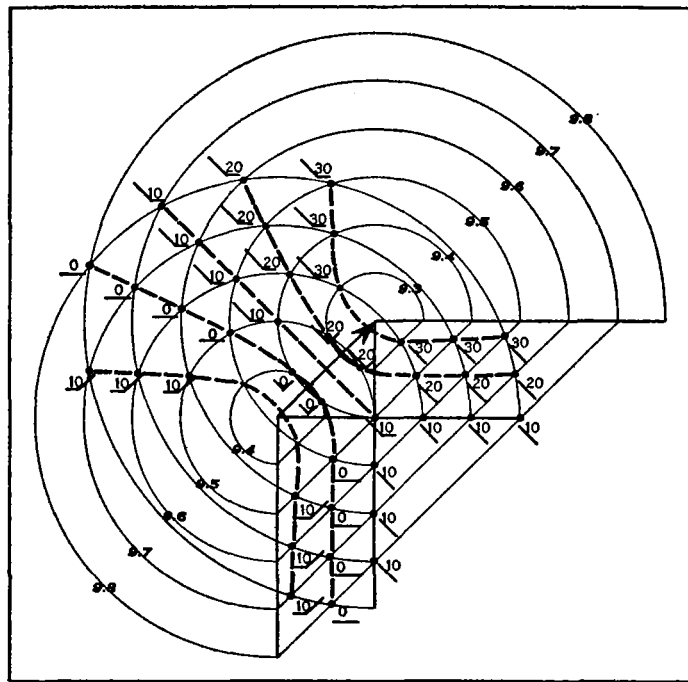


FIGURE 3.

the line where tendencies have been either falling (or steady) followed by a rise.

Figure 2 represents a cyclone without frontal structure and no change in intensity. In this case, tendencies in

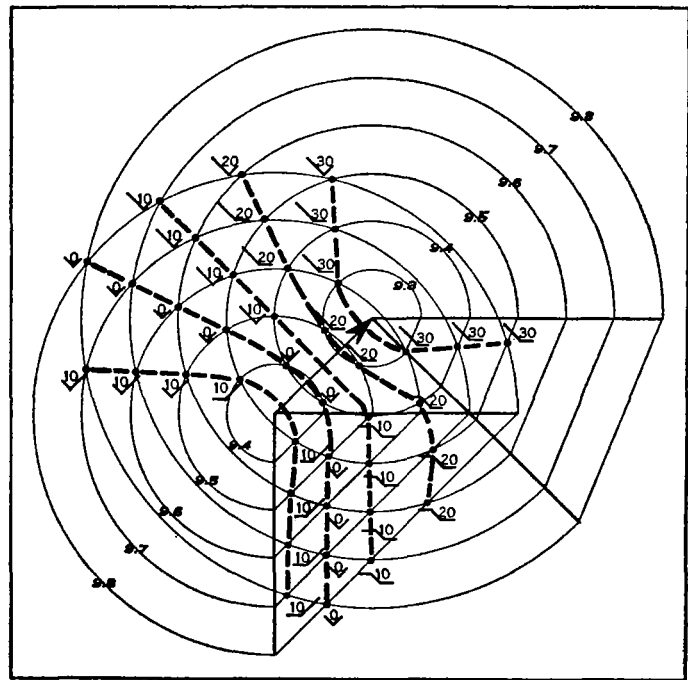


FIGURE 4.

the southeast portion show no leveling off as is found in the warm sector of figure 1 although they are falling less rapidly than during the early part of the period.

Since provision is not made in our code to distinguish between falling then steady and falling then falling less

rapidly, the characteristics in the latter case might be mistaken to indicate the existence of a frontal structure.

Figure 3 represents a warm-sector cyclone which is increasing in intensity (deepening) with the cold and warm fronts retaining the same positions relative to the moving system. We find that deepening plays an important role in this case and that tendencies would be reported as steadily falling in the warm sector. Unless the deepening is taken into consideration in such a case, the probability is that the warm front would be placed too far south and the cold front too far west.

If the disturbance is occluding rapidly with increasing intensity, as shown in figure 4, we find characteristics behind the cold front that cannot be indicated in our code. The warm sector and warm-front boundary are distinguished by the same characteristics as figures 1 and 3.

The writer has represented all the models as having a northeastward movement. If the reader wishes to consider any other direction it may be done by rotating the diagram the appropriate number of degrees; the characteristics and tendencies will be unchanged.

When considering the tendencies and characteristics as criteria for location of fronts, the forecaster should keep in mind whether the cyclone is increasing, decreasing, or is unchanged in intensity, as well as the direction of movement. If other elements do not necessarily indicate the existence of a front and the tendencies can be explained by the above considerations, then it is highly probable there is no front. In this connection the writer wishes to call attention to cold fronts aloft. In many cases, simple movement of the system will give tendencies which might be interpreted as being associated with a cold front aloft. Therefore, caution should be exercised in locating such a front unless other data, e. g., cloudiness, precipitation, or upper-air soundings, indicate its existence.

It is observed from the models that the deeping or filling tendency is indicated by the 3-hour isallobar (amount of change regardless of characteristic) which crossed the path of the cyclone half way between successive 3-hour positions of the center. While we do not have synoptic maps at 3-hour intervals, many stations do prepare 6 hourly maps on which the deepening or filling tendency obviously will be found one-fourth of the distance between the present center and the location 6 hours before. If the maps are 12 hours apart then the distance will be one-eighth. To determine the amount of tendency at the point in question, the 3-hour isallobars should be carefully drawn and the distance measured accurately.

For example, suppose we have a cyclone with  $-0.04$  tendency one-fourth of the distance from the present center to the position 6 hours before. Then the cyclone should deepen with central pressure 0.16 and 0.32 lower, 12 and 24 hours later, respectively.

This method of computing deepening is valid for occluded cyclones and for warm-sector cyclones which do not occlude during the period for which computation is made.

Warm-sector cyclones on the basis of the above principle will almost invariably show either deepening or unchanging intensities. However, as soon as a cyclone occludes, it usually begins to fill, and deepening should not be calculated beyond the time occlusion is expected to occur.

Computations of deepening or filling are made on the assumption that there will be no change in the rate, which does not introduce large errors unless the time interval is large. Computation beyond a 24-hour period is not recommended.

It has been shown by Petterssen<sup>1</sup> that a pressure system moves normal to the isallobar that passes through the center. Since the pressure tendencies are composed of two parts, that is, partly due to deepening or filling and another part due to movement, we can quickly get a good estimate of the subsequent displacement of the center over a period of 12-24 hours.

In symbols, we have

$$D = N(T_b - T_a) + P_a$$

Where

$D$  = displacement in terms of pressure.

$T_b$  = deepening or filling tendency.

$T_a$  = tendency at the center.

$P_a$  = Pressure at the center.

$N$  = Number of 3-hour periods, e. g., displacement 24 hours hence,  $N=8$

The displacement is shown by the point where the pressure  $D$  intersects the normal to the isallobar that passes through the center.

Example:

$$T_b = 0$$

$$T_a = -0.04$$

$$P_a = 29.68$$

$$N = 8$$

$$D = 8(0 + 0.04) + 29.68 = 0.32 + 29.68 = 30.00$$

## TEMPERATURE CHANGES IN NORTH AND SOUTH CAROLINA

By EARL C. THOM

[Aerological Division, Weather Bureau, Washington, November 1, 1937]

From a climatic standpoint temperature is generally considered to be of first importance. Hann says: (1) "Temperature is certainly the most important climatic element." All works on climate, meteorology, and forecasting treat the subject of temperature in considerable detail. (2) Much space is given to mean temperature, over various periods of time. Mean maximum and minimum temperatures, diurnal variation, and variations with elevation have been discussed. Tabulations of such temperature items as average departure from normal, greatest daily range, monthly extremes (3), and average 8 a. m., noon, and 8 p. m. temperatures, are to be found (4); but, aside from information on cold waves (5) and two studies on temperature changes affecting Texas (6), little is available treating the subject of changes in temperature from day to day.

This phase of climate is of great practical importance. The daily changes in temperature during any season and especially the occurrence of sudden or unusually large changes affect the plans, habits, and actions of all. The forecasters of the United States Weather Bureau have recognized this and nearly half of all the forecasts have dealt with expected temperature changes.

The Weather Bureau also recognizes the fact that there are differences in the effects of day-to-day temperature changes in the different seasons. During the late fall, winter, and early spring there are more and larger temperature changes than in summer. People become accustomed to larger temperature variations and a considerably larger change is necessary in winter than in summer to produce the same effects. When stationary temperature has been forecast the change which may occur and still allow the